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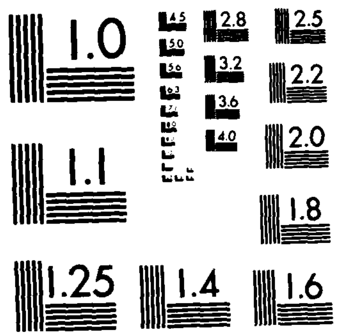
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# AN EVALUATION OF THE PERCEIVED EFFECTIVENESS OF RELIABILITY IMPROVEMENT WARRANTIES (RIW) APPLIED DURING THE AIR FORCE RIW TRIAL PERIOD

Captain David R. Parkinson, USAF
Captain Alan W. Schoolcraft, USAF

LSSR 58-83





DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Reliability Improvement Warranties (RIWs) were implemented by the U.S. Air Force in 1974, as the beginning of a RIW trial period. Six major Air Force programs have used RIWs since the trial period began. The Air Force Director of Contracting and Manufacturing Policy (HQ USAF/RDC) requested that the RIW trial period be concluded and that the effectiveness of the Air Force's use of RIWs during the trial period be evaluated. This research effort was an attempt to evaluate the effectiveness of RIWs during the trial period and to provide recommendations for the future use by the Air Force of the RIW concept. RIW experts involved with each of the six Air Force RIW programs were interviewed and asked to rate eleven RIW effectiveness criteria, and to provide recommendations for the future use of the RIW concept. In addition, the RIW experts were asked to respond to open-ended questions of interest to the research effort. The research team concluded from the nonparametric statistical tests that the RIW experts perceived that the Air Force RIW program during the trial period was effective, and that the experts recommend continued use by the Air Force of the RIW concept.

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# AN EVALUATION OF THE PERCEIVED EFFECTIVENESS OF RELIABILITY IMPROVEMENT WARRANTIES (RIW) APPLIED DURING THE AIR FORCE RIW TRIAL PERIOD

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Management

By

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September 1983

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This thesis, written by

Captain David R. Parkinson

and

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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# THE RESEARCH PROBLEM

## Introduction

In recent years, reliability has been discussed primarily with other logistics terms such as maintainability and availability. This important triad of concepts which, when linked together, form the basis for operational readiness and combat effectiveness. In speaking about the mission of the Air Force Logistics Command (AFLC), its Commander, General James P. Mullins, says, ". . . our task is to provide quality products and services on time to the operational commands [19:29]." Over the last several years, quality and reliability have been used interchangeably to mean the same thing. The Air Force defines quality as ". . . the composite of material attributes including performance features and characteristics of a product or service to satisfy a given need [26:563]." An important material attribute is reliability which the Air Force defines as ". . . the probability that an item will perform its intended function for a specified interval under stated conditions [26:576]." General Mullins, again, on AFLC says, "Our ultimate objective, of course, is to influence the design of hardware, to design in reliability and maintainability wherever possible [19:28]."

We can no longer ignore the realities of technological change and limited defense budgets. Due to the technological expansion in the defense industry since World War II, Department of Defense (DOD) weapon systems are more sophisticated, complex, and expensive. The challenge to achieve increased reliability in these more sophisticated and complex weapon systems at least cost requires innovative and creative management. The DOD has accepted that challenge by implementing a contracting technique called Reliability Improvement Warranties (RIWs).

## Background

The concept of RIW was presented to each military department's Assistant Secretary for Research and Development, Installation and Logistics (R&D/I&L) in August 1974 in a memorandum released by the Assistant Secretary of Defense for Installation and Logistics (I&L) (3:1). The memorandum stated that as part of the DOD's efforts to improve operational reliability and reduce costs, RIWs should be used on a trial basis in the acquisition process in order to help determine the scope and benefits that RIWs might have for the DOD and, ultimately, the Air Force.

Previously known as a "Failure Free" or "Standard Warranty," the primary objective of a RIW is to provide the contractor with an incentive to design and produce equipment

with high reliability, and to reduce repair costs during the warranty period in order to maximize contractor profits (29:1-2).

Under the RIW concept, a contractor is obligated, within the terms of the contract, to accomplish repair and replacement of failed equipment at a firm-fixed price for the duration of the warranty period. If equipment failure occurs during the warranty period, the failed equipment is returned to the contractor for repair and replacement at no cost to the user. Figure 1-1 depicts how a typical RIW contract functions.

In response to the Office of the Secretary of Defense (OSD) request and based on the basic RIW concept, the Air Force began applying RIWs to selected avionics systems. Through 1982, Air Force RIWs have been applied on the following avionics subsystems:

- AN/ARN 118 TACAN
- Carousel IV Inertial Navigation System (INS)
- C-141 Attitude Heading Reference System (AHRS)
- OMEGA Navigation Set
- F-16 Electronic Components [Radar, Navigation Unit, Flight Control Computer, Heads Up Display Unit (HUD), and associated line replaceable units (LRU)]
- Air Force Standard Inertial Navigation Unit (INU)

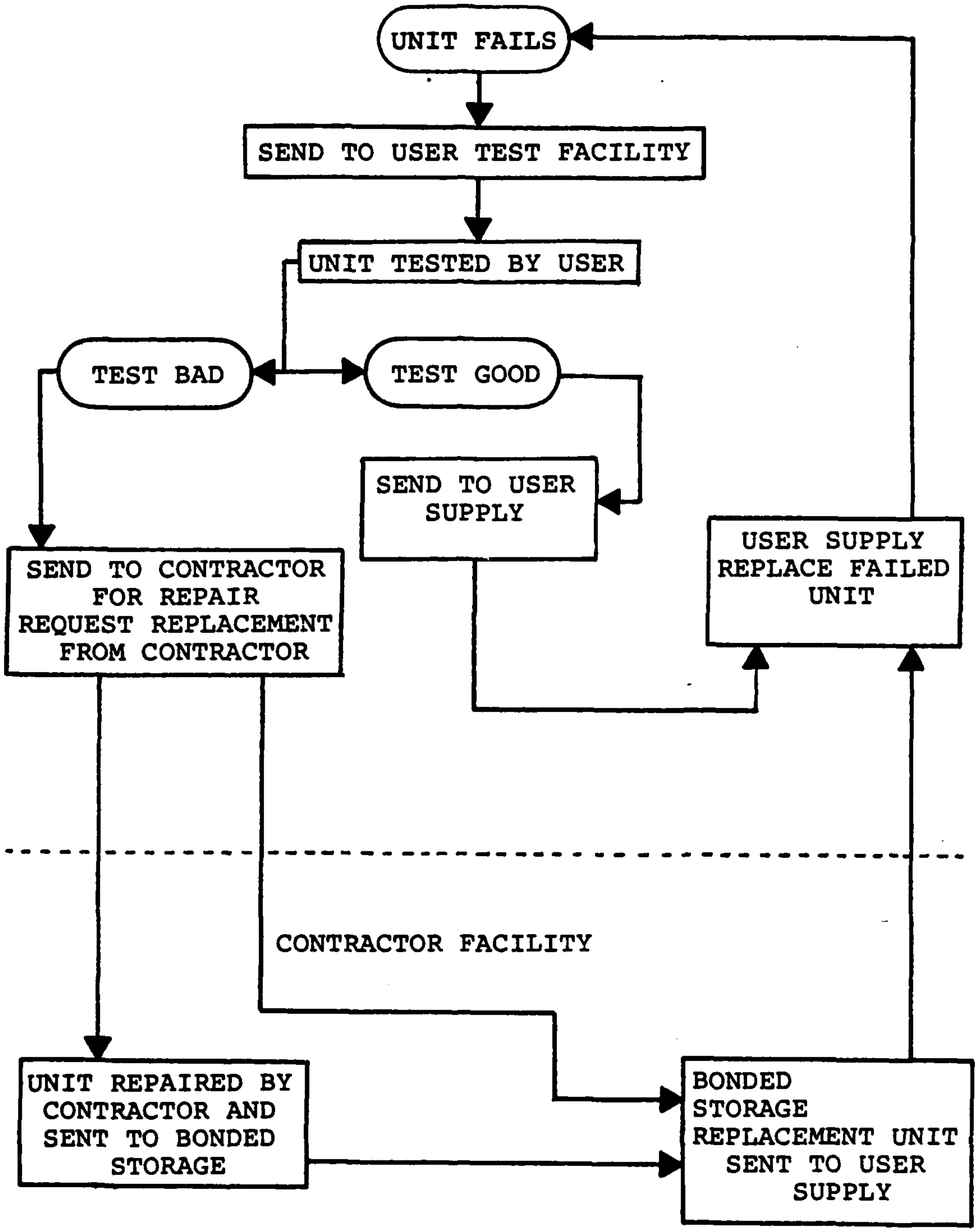



Fig. 1-1. RIW Pipeline

Since the implementation of the Air Force RIW trial period, little ongoing analysis of these subsystems were performed to determine the effectiveness of RIWs, which was indicated in a 1979 Air Force Audit Agency (AFAA) audit report (1:1-10).

## Problem Statement

Since the Air Force's RIW trial period must be closed, there was a need to evaluate the effectiveness of RIWs applied during the trial period, and to recommend the future use of the Air Force RIW contracting concept.

## Justification

The Air Force RIW trial period began in 1974 (27:1). Periodic assessments were required during the period to determine if the RIW approach was achieving its reliability and cost objectives (27:20-21). In March 1979, an AFAA audit report on the Impact of New Management Concepts on Support and Maintainability of Avionic Equipment identified weaknesses in the RIW approach. One relative weakness was:

> A master plan for evaluating the impact of the RIW concept on Air Force programs and concluding the trial program was not prepared. Data accumulated for possible use in the evaluation were incomplete and untimely. Therefore, the ability to assess the value of existing RIW programs was reduced [1:20].

Subsequent to this initial report, the Air Force Director of Contracting and Manufacturing Policy (HQ USAF/RDC) was established as the Office of Primary Responsibility (OPR) for

RIW (1:6). In November 1982, an AFAA draft report on F-16 Weapon System Acquisition and Logistic Support Management recommended that the Air Force trial RIW program be concluded, and the cost effectiveness of meeting reliability and maintainability objectives be assessed (7:2). In response to this second AFAA report, HQ USAF/RDC asked the Deputy Chiefs of Staff for Contracting and Manufacturing at both Headquarters Air Force Logistics Command (HQ AFLC) and Headquarters Air Force Systems Command (HQ AFSC) to provide recommendations on the overall effectiveness of the RIW approach and bring the trial period to a close (7:1). Currently, within AFLC and AFSC respectively, the Air Force Acquisition Logistics Division (AFALD) and Aeronautical Systems Division (ASD) are evaluating the RIW concept and will provide their recommendations to the Air Staff by 31 July 1983. This research report will be an independent evaluation of Air Force RIW programs during the trial period and will be an important aid to Air Force decision makers in evaluating the effectiveness of the RIW concept.

## Research Objectives

1. To determine if RIWs applied to Air Force programs since August 1974 were effective.

2. To recommend the future use by the Air Force of the RIW concept.

## Research Questions

1. What are the perceptions of active duty Air Force officers and DOD civilians with Air Force RIW expertise regarding the effectiveness of RIWs as applied to Air Force programs since August 1974?

2. What is the recommendation for the future use by the Air Force of the RIW concept, as perceived by Air Force officers and DOD civilians with Air Force RIW expertise?

## Supporting Qualitative Research Hypotheses

The research hypotheses to answer Research Question One are:

1-6. Active duty Air Force officers and DOD civilians with Air Force RIW expertise perceive the

(1) AN/ARN-118 TACAN

(2) C-141 AHRS

(3) OMEGA Nav Set

(4) Carousel IV INS

(5) F-16 Electronic Components

(6) AF Standard INU

RIW program as ineffective.

7. Active duty Air Force officers and DOD civilians with Air Force RIW expertise perceive the Air Force RIW program as ineffective.

The research hypothesis to answer Research Question Two is:

8. Active duty Air Force officers and DOD civilians with Air Force RIW expertise do not recommend the continued use by the Air Force of the RIW concept.

## General Research Plan

This section presents a brief overview of the generalized approach to the research. The general research plan concentrates on the perceptions of active duty Air Force officers and DOD civilians with Air Force RIW expertise regarding effectiveness of the Air Force RIW program. The instrument for obtaining these perceptions is a formal interview. The interview is divided into the following four sections: General/Demographic, Program Evaluation, Future Recommendation, and Open-Ended Questions. Responses to the Program Evaluation section are assigned to the research hypothesis associated with Research Question One; while responses to the Future Recommendation section are assigned to the research hypothesis associated with Research Question Two. To evaluate each of these research hypotheses, nonparametric statistical tests are used to measure the perceptions of the respondents. Finally, the General/Demographic section is used to document the credibility of the respondents, and the Open-Ended Questions section is used to support the two research questions.

Through the use of this general research plan, this research team will develop supporting hypotheses to answer the two research questions. Answers to these questions will meet

the stated research objectives which, in turn, will address the problem statement (Figure 1-2).

## Definitions

The following terms used throughout this report are defined as follows:

### Life Cycle Cost (LCC)

The LCC of a system is the

> . . . sum total of the direct, indirect, recurring, and nonrecurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance and support of (that) system over its anticipated useful life span [29:3].

### Mean Time Between Failure (MTBF)

A time expressed in hours quantified by dividing mean operating hours by the mean number of failures.

### Reliability Improvement Warranty (RIW)

A provision in either a fixed price acquisition, or fixed price equipment overall contract in which:

1. The contractor is provided with a monetary incentive (by being allowed to retain all savings accrued due to reduced contractor support costs during the period of warranty) throughout the period of the warranty to improve the production, design, and engineering of the equipment so as to enhance the field/operational reliability and maintainability of the system/equipment.

2. The contractor agrees that, during a specific or measured period of use, he will repair or replace (within a

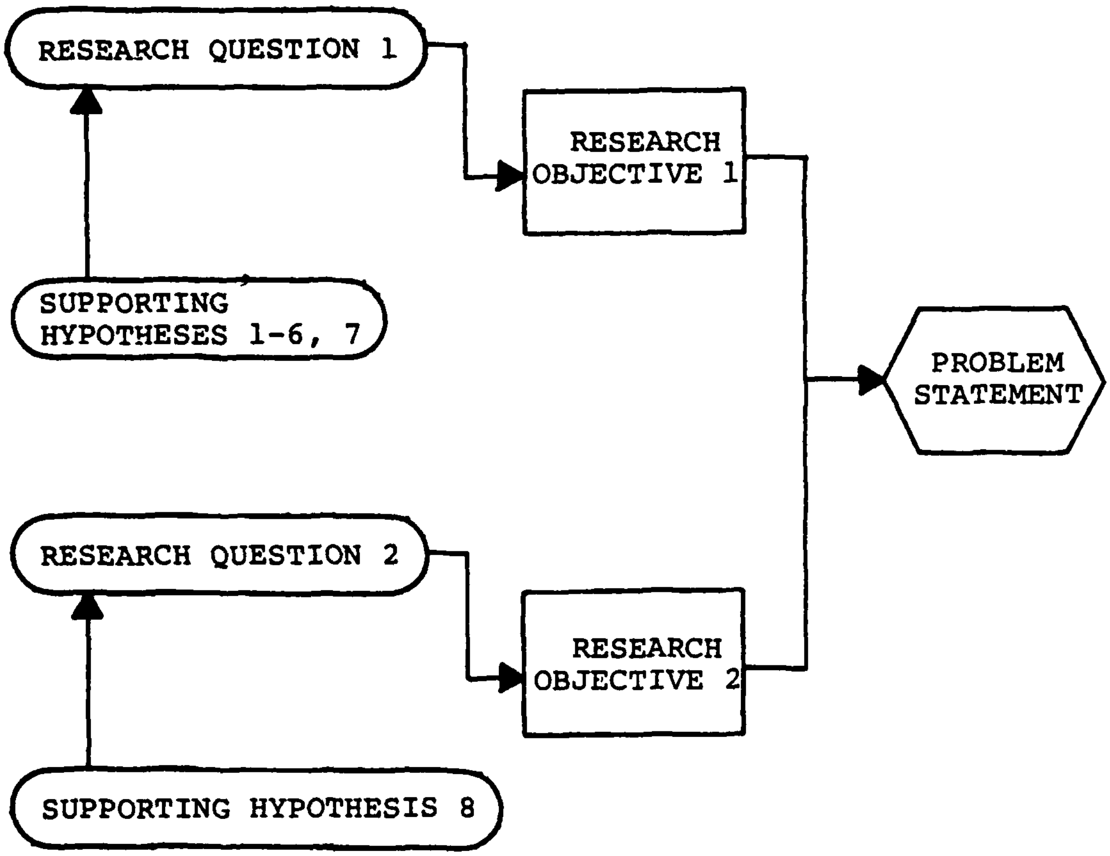



Fig. 1-2. Research Plan

specified turnaround time) all equipment that fails (subject to specified exclusions if applicable) (27:5-6).

## Turnaround Time

Time interval from receipt of a failed unit at the manufacturer's dock until receipt of the repaired unit at a Government-bonded warehouse.

## Warranty

A warranty is a promise of affirmation given by a seller to a purchaser regarding the nature, usefulness, or condition of the supplies or performance of services to be furnished. The principal purposes of a warranty in a Government contract are to delineate the rights and obligations of the contractor and the Government for defective items and services and to foster quality performance. Generally, warranties survive acceptance of the contract items for a stated period of time or use, or until the occurrence of a specified event, notwithstanding other contractual provisions pertaining to acceptance by the Government (27:Sec.2:55).

## RIW with MTBF Guarantee

A basic RIW contract with the added incentive to assure that the contractor's equipment achieves a specified MTBF by the end of the RIW period. The MTBF guarantee may include provisions for reliability growth (increase MTBF) as the equipment matures.

## Effectiveness

The quality or state of being able to produce a definite or desired result as indicated by increased reliability, maintainability, contractor competition, use rate, and RIW contract clause, and reduced acquisition cost, equipment modification, data collection, supply system, maintenance skills, and number of spares.

## Research Report Overview

As an overview of this research report, the content of the remaining chapters is briefly discussed.

Chapter II is a review of the literature applicable to the subject of reliability improvement warranties. This literature describes RIWs in the Commercial Airline industry, in the Department of Defense, and in the United States Air Force. Literature discussing past and present Air Force RIW programs is reviewed. Finally, this chapter reviews the research which discusses the effectiveness of RIWs.

Chapter III describes the methodology used to accomplish the research objectives and answer the research questions discussed in Chapter I. This chapter describes the population from which data were gathered, the interview instrument used to collect the data, and the procedures to process and analyze the data. Finally, scope, limitations, and assumptions of the research are described.

Chapter IV contains an analysis of the data collected by the survey instrument. The procedures described in Chapter III will be used to process and analyze each iteration of the survey instrument.

Chapter V summarizes the conclusions that can be drawn from this study of the effectiveness of Air Force RIWs during the trial period. Recommendation for future use of Air Force RIWs are made, and recommendations for future research are suggested.

# CHAPTER II

# LITERATURE REVIEW

## Introduction

The Department of Defense (DOD) has focused attention on assuring that our defenses are prepared to fight with the most technically up-to-date and reliable equipment. With the sophistication and complexity of DOD weapon systems increasing, the challenge to insure readiness and system availability is through increasing the reliability of our systems at the least possible cost. The focus of much of this challenge is on those systems and subsystems which most often lead to poor availability because of deficiencies in reliability and maintainability (20:1). This emphasis cannot be understated nor taken for granted. Senator William Proxmire (D-Wis), in prefacing the testimony of a recent Central Intelligence Agency report, says

> The Soviet Union has built an exceedingly powerful military force. Under Kruschev the emphasis was on strategic nuclear programs, but Brezhnev presided over an across-the-board expansion and modernization of all Soviet forces [25:4].

One effort to curb the rising costs of weapon systems and, at the same time, insure operationally ready equipments to meet the Soviet threat, the DOD has implemented a concept

known as the Reliability Improvement Warranty. This concept is an outgrowth of historical experience with the commercial airlines.

## Commercial Airline Experience

The airlines use a form, fit and function interchangeability concept for much of their avionics equipment. Since the 1930s, this has been part of the commercial airline acquisition methodology (CAAM), a primary feature is to use warranty clauses in acquisition contracts (16:16). Pan American Airlines, Inc., with over $1 billion invested in 747 aircraft, wanted to reduce the high support cost risks associated with poor equipment reliability in their aircraft fleet (16:11). In doing so, Pan American specified a guaranteed mean time between failure (MTBF) which would be achieved by the end of the five-year warranty period (16:12). As a result of this airline experience, Aeronautical Radio, Incorporated (ARINC), the communications advisory board of the U.S. Air Transport Industry, developed a list of CAAM guidelines which form the present basis of the DOD RIW guidelines. While the warranty approach was, in theory, a sound one, the Rand Corporation reported in 1977 that the airlines were unable to reduce life-cycle costs by use of a warranty (10:43). The report goes on to say, ". . . the justification of warranty usage in the military on the basis of better MTBFs in commercial avionics is misleading [10:43]."

Notwithstanding this report, the DOD implemented the use of warranties in weapon system acquisitions to improve reliability.

## Failure Free Warranty (FFW)

The emphasis on reliability evolved out of the early 1960s, in which a joint Air Force Logistics and Systems Command concept to determine the true cost of procurement, was expanded to include a product-life warranty system in the life-cycle cost area (21:7). This led to a proposal from the Instruments Division of Lear Siegler, Incorporated (LSI) to repair or replace MD-1 vertical gyros under a failure free warranty concept. The proposal was not accepted by the Air Force, but it did set the foundation for use by the Navy.

In 1967, the Navy awarded the first FFW contract to Lear-Siegler to repair gyroscope platforms on Navy A-4 and F-4 aircraft (22:12). The LSI proposal included a fixed price for repairing gyros over a specified operating time period. It was subsequently reported that over the five-year warranty period the MTBF increased 33 percent and repair costs were reduced by 40 percent (17:51). By 1969, the Air Force implemented a FFW concept on the F-111 displacement gyro. Terms of the contract specified 3,000 operating hours or five years, whichever came first (22:12A). Under this contract, acquisition costs were reduced 37 percent. The warranty price over the five-year period was 7 percent of the

per unit acquisition cost (22:18). Reliability of the gyros, however, decreased over the warranty period for unknown reasons (22:19-20). Realizing the potential for reliability growth and reduced support costs, the DOD implemented the RIW trial period in 1973.

## Department of Defense Trial Use of RIW

The DOD trial period was initiated in August 1973 with an Assistant Secretary of Defense for Installations and Logistics (I&L) memorandum which directed trial use of RIW by the services ". . . in the acquisition and initial operational support of a number of Electronic Subsystems [4:1]." Following the ASD (I&L) memorandum, a Reliability Improvement Warranty Committee was formed to prepare definitive OSD policy on RIW applications (3:2). In essence, this committee was responsible for formulating the RIW guidelines. In August 1974, the Assistant Secretary of Defense for Installations and Logistics sent the guidelines to all three services for implementation (3:1-20). An important concept in the RIW approach, as stated in the memo, was:

> . . . thus, the intent of the RIW contracting technique is to realize improved operational reliability and maintainability of DOD systems and equipments for each additional dollar that the contractor uses. For these reasons, a RIW is not a maintenance contract and, therefore, should not be used for this purpose [3:1].

In response to this direction from DOD, the Air Force established interim guidelines to implement this concept.

## Air Force Trial Use of RIW

In 1964, Air Force Operational and Maintenance (O&M) costs accounted for 21 percent of the Air Force budget; and in 1973, O&M costs were responsible for 27 percent of the Air Force budget (11:p.6-2). With Air Force O&M costs rising and defense budgets constrained, it became apparent that acquisition and support costs must be reduced. In July 1974, the Directorate of Procurement Policy at HQ USAF published the "Interim Reliability Improvement Warranty (RIW) Guidelines." The primary emphasis behind the trial period, as stated in the guidelines, is as follows:

> The essence of the RIW philosophy is that during the period of the warranty coverage, for a fixed price, contractors will be encouraged to improve the reliability and to reduce the repair costs of their equipment through the mechanism of "no-cost" (to the Government) Engineering Change Proposals (ECPs). These ECPs shall be consistent with Government procedures to preserve Configuration Control. Once a fixed price is established for the RIW, the actual profit realized by the contractor is dependent upon the equipments' reliability and maintainability in service use, plus any improvements that he can make in its reliability and maintainability so as to keep the number and cost of repairs as low as possible [27:4].

The emphasis of the RIW is to focus contractor attention on designed-in reliability and maintainability. The guidelines, thus, go on to say,

> . . . as RIW becomes a contracting technique by which the Government derives the benefits of improved reliability and maintainability for each additional dollar that the contractor earns [27:4-5].

Prior to use of the RIW approach, contractors had little incentive to improve reliability. As can be seen in Figure 2-1, the contractor, under a non-RIW situation, will be motivated to design and produce at minimum specified reliability beyond required specifications (14:24). However, with the RIW approach, the cost curves which go into describing overall profit for the contractor are shown in Figure 2-2. It should be noted that now the support costs, as well as initial production costs, effect total costs of the contractor. In this case, the management of costs associated with the RIW are transferred to the contractor. From the total cost curve in Figure 2-2, the contractor can maximize profit by making appropriate trade-offs between cost and reliability. Assuming a constant contract price of the buyer (the Government), the contractor will produce where profit is maximum--at the minimum point (A) on the total cost curve and, at this point, reliability (MTBF) is greater than the minimum acceptable reliability. It can be seen that the contractor is encouraged to introduce design changes early in production, which can result in higher initial costs, but can be offset by reduced support costs (2:15).

The guidelines also set forth a number of criteria against which potential systems and subsystems must be evaluated to determine if they lend themselves to RIW application. The guidelines were tailored for application to avionics equipments. This is due, in part, to the expense,

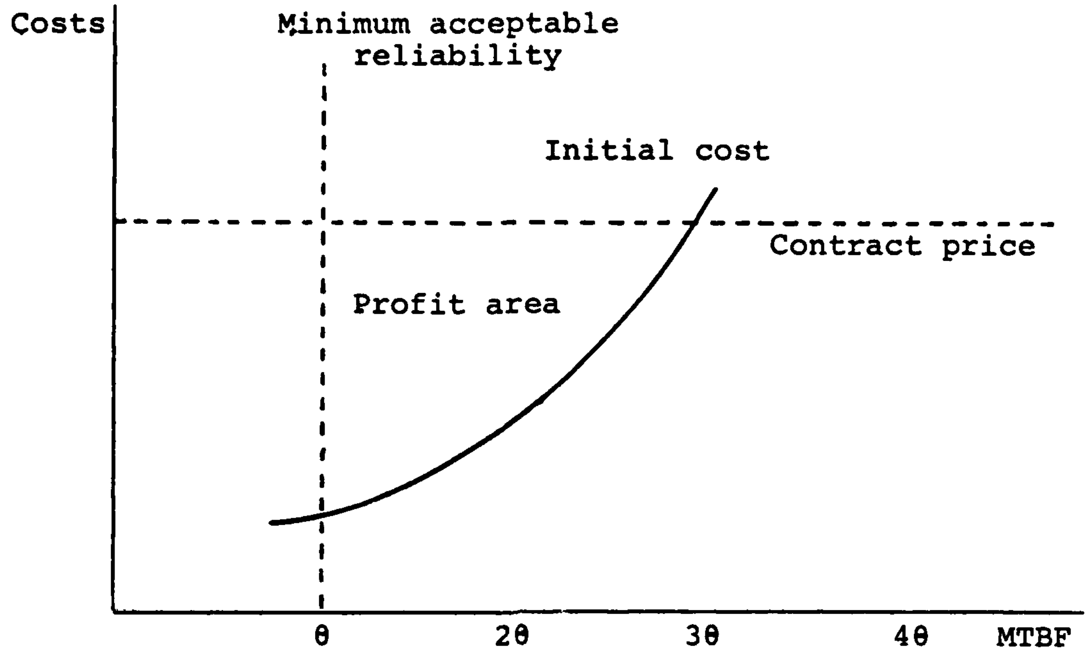



Fig. 2-1. Non-RIW Profit Motive (14:24)

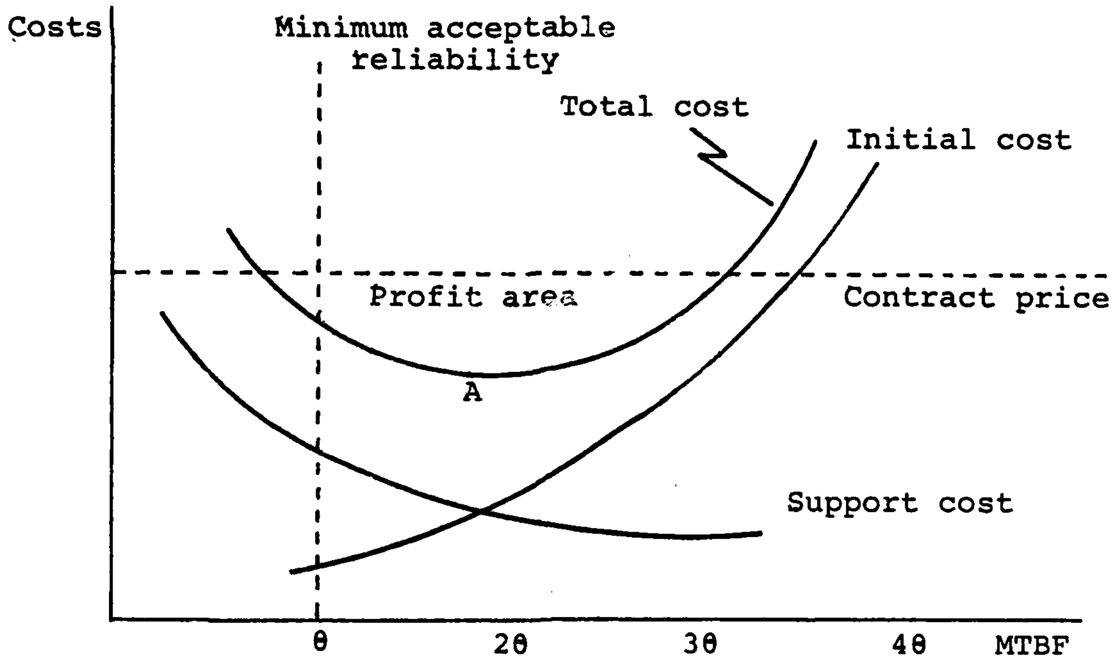



Fig. 2-2. RIW Profit Motive (14:24)

complexity and sophistication of avionics equipment, as well as the Air Force investment of nearly $12 billion in this equipment which must be maintained and supported (1:1). As stated in the RIW guidelines, the applications criteria are as follows:

1. A warranty can be obtained at a price commensurate with the contemplated value of the warranty work to be accomplished, with consideration being given to the contractually specified R&M requirements.

2. Moderate to high initial support costs are involved.

3. The equipment is readily transportable to permit return to the vendor's plant or, alternatively, the equipment is one for which a contractor can provide field service.

4. The equipment is generally self-contained, is generally immune from failures induced by outside units, and has readily identifiable failure characteristics.

5. The equipment application in terms of expected operating time and the use environment are known.

6. The equipment is susceptible to being contracted for on a fixed price basis, with competition on the basis of form, fit and function stimulated to the extent practicable.

7. The contract can be structured to provide a warranty period of from three-five years. This should allow the contractor sufficient time to identify and analyze failures in order to permit reliability and maintainability improvements.

8. The equipment has a potential for both reliability growth and reduction in repair costs.

9. Potential contractors indicate a cooperative attitude toward acceptance of an RIW provision and evaluation of its effectiveness.

10. A sufficient quantity of the equipment is to be procured in order to make the RIW cost-effective.

11. The equipment is of a configuration that discourages unauthorized field repair, preferably sealed and capable of containing an Elapsed Time Indicator (ETI) or some other means of usage indication.

12. There is a reasonable degree of assurance that there will be a high utilization of the equipment.

13. The equipment is one that permits the contractor to effect no-cost ECPs subsequent to the Government's approval.

14. Failure data and the intended operational use data can be furnished the contractor for the proposed contractual period and updated periodically during the term of the contract.

It is noted that the equipment need not meet all the criteria shown above in order to apply an RIW. Rather, at this point in time, we should pick logical candidates meeting several or many of the criteria so that further assessment can be made of the value of this technique (27:15-16).

While determining which equipments are appropriate for RIW, application is an important first step in the process; insuring that RIW is cost-effective is a crucial second step.

## Determination of Cost-Effectiveness of RIW

It is not general practice in the Air Force, or DOD for that matter, to contract separate systems, one with RIW and one without, to determine which approach is the most cost-effective. For this reason, the RIW guidelines state,

> . . . a cost analysis should be performed for each proposed warranty application, upon receipt of the contractor's proposal, in order to determine whether the use of an RIW would be cost-effective. Such an analysis should investigate the relative cost of the RIW and non-RIW situations (including ECPs) and examine the cost of varying time periods [27:12].

As part of the overall cost benefit analysis, in addition to knowing firm contractor costs for the RIW, it is necessary to determine what (the Air Force) would have paid in support costs for the same system under a non-RIW application. These cost analyses, thus, become the basis for the comparisons to determine the most cost-effective approach over the total life-cycle of the system or subsystem. These guidelines established the foundation for the Air Force programs which have applied the RIW concept.

## Air Force Experience with RIW

Since the trial period began for the Air Force in 1974, six programs have implemented the RIW concept. Of the

six, the F-16 System Program Office warranted nine Line Replaceable Units (LRUs) through a single contract with the prime airframe contractor, General Dynamics. Table 2-1 shows the program breakout by contractor and warranty period.

In July 1975, the AN/ARN-118 TACAN was the first Air Force program to use the RIW-type contract. The contract specified a minimum reliability of 500 hours MTBF approximately two years after contract award. Reliability growth to 800 hours MTBF was expected within 46-69 months after contract award (21:22).

In November 1975, the Air Force awarded its second major RIW contract for the Carousel IV inertial navigation system (INS) to Delco Electronics. The minimum acceptable MTBF for proposal purposes was 750 hours; Delco bid 1,128 hours (21:28).

In 1976, the F-16 program initiated a major effort on the part of the Air Force in awarding a RIW contract to General Dynamics. As noted in Table 2-1, nine LRUs were covered by the contract. A unique aspect of the program is that the RIW applied not only to the first 250 Air Force aircraft installs, but to the first 192 installs in those aircraft purchased by the European Participating Governments (13:p.4-1). Of the nine LRUs, only two contain a RIW with MTBF guarantee--the Radar Transmitter and the Heads-up-display (HUD) Electronics.

TABLE 2-1

MAJOR AIR FORCE APPLICATIONS
OF RIW (13:40)

| Program | Contractor | Warranty Period |
|---|---|---|
| AN/ARN-118 TACAN | Collins Avionics Rockwell Int'l | 5 yr |
| C-141 AHRS | Lear-Siegler, Inc. | 5 yr |
| OMEGA Nav Set | Dynell Electronics | 5 yr |
| Carousel IV INS | Delco Electronics | 5 yr |
| F-16 Electronics | General Dynamics | 4 yr |
| Flt Control Computer | Lear-Siegler | or |
| Radar Antenna | Westinghouse | 300,000 flight hours (whichever comes first) |
| Radar lo Power RF | Westinghouse | |
| Radar Digital Processor | Westinghouse | |
| Radar Computer | Westinghouse | |
| Radar Transmitter | Westinghouse | |
| Heads-Up-Display | Marconi-Elliot | |
| HUD Electronics | Marconi-Elliot | |
| Inertial Nav System | Singer-Kearfott | |
| AF Standard INU | Litton Guidance and Control | 5 yr |

In a more recent trial of RIW, the Air Force's Standard Inertial Navigation Unit (INU) awarded a five-year RIW with MTBF guarantee to Litton Industries, Guidance and Control Division. Reliability at the first measurement period (one year after delivery of the first production INU) was to be 275 hours MTBF. Growth over five years is to achieve reliability of 525 hours, after three more measurement periods over the warranty period.

According to a 1979 report (24:68), the RIW trial phase has indicated measures of success with increases in MTBFs at reduced costs. The report goes on to say, however, that an evaluation of the effectiveness of the RIW is yet to be made.

## Effectiveness of RIW

Since the Air Force followed suit with the airlines' practice of using warranties for avionics, the researchers would expect lessons on how and what to measure to determine RIW effectiveness. But, as a 1979 Rand report points out, warranties and their effects are not completely understood even by the airlines and, as such, ". . . they have developed no standard by which to measure the cost-benefit derived from warranties [10:2]." In the same report, observations on the DOD RIW trial period were made. The authors suggest that the value of RIW over the trial period will yield inconclusive evidence due primarily to varying contractual complexities

between programs and, more importantly, the lack of a well-defined plan by which the RIW can be evaluated (10:54). Along the same lines, a RIW workshop reported that it was the contractual issues, not technical, which posed the greatest problems for the RIW (8:2).

In a revealing analysis which evaluated and recommended changes to the RIW guidelines, Jacobson and Skaggs concluded that inadequacies in the existing guidelines may limit overall effectiveness of the RIW approach (16:64-69). According to a 1976 report, industry believes that, while the DOD is serious about the use of RIW now and in the future, the RIW trial period should be suspended until the guidelines can be revised. Their concern centers around the implied use of RIW for any new equipment whose design may use a new technology without the benefit of prior field experience (5:11).

## Conclusions from the Literature

In reviewing the literature on the Reliability Improvement Warranty concept and its impacts, many parallels were observed among research reports. What follows are this research team's three most prevalent conclusions drawn from this review.

1. Reliability Improvement Warranties are not a cure-all for Air Force reliability and maintainability problems but, when applied, implemented, administered, and evaluated in accordance with the principles of the RIW

guidelines, have the potential for achieving reliability, maintainability and cost objectives.

2. Neither the Government nor industry fully appreciate the RIW concept to the extent required for both parties to realize benefits therefrom.

3. There is no "watch dog" within the Air Force to monitor the progress of RIW throughout the trial period. While theoretically sound policy was disseminated, there has been little follow-up action to assure compliance with the direction and policy.

The research which follows is not intended to solve the RIW effectiveness issue, but merely shed some new light on a somewhat clouded problem area.

# CHAPTER III

# RESEARCH METHODOLOGY

## Introduction

In Chapter I, the basic problem and formulated research questions were defined. This chapter outlines the methodology used in answering the research questions. The research team identifies and interviews experts in the field of RIW, develops an interview instrument to gather the data, and describes the statistical and descriptive analyses to be performed on the data gathered by this research. Finally, the assumptions, scope and limitations of this research effort are presented.

## Identification and Interview Procedure

### Identification of RIW Experts

The first step in the process was to identify those individuals with Air Force RIW expertise. Individuals were chosen from two target populations: (1) active duty Air Force officers and DOD civilians currently involved in one of the six previously identified Air Force RIW programs; and (2) active duty Air Force officers and DOD civilians previously involved in one of the six Air Force RIW programs. The sample

was drawn from these two target populations and consisted of individuals

1. whose opinions and judgment were sought;

2. from the disciplines of program management, contracting and logistics management; and

3. who were willing to participate in the research.

From the drawn sample, two criteria were used to identify the experts:

1. They must have a basic knowledge of the problem area and be able to apply that knowledge.

2. They must have experience formulating, implementing or monitoring an Air Force RIW program.

It was assumed that two years in program management, contract management, or logistics management on any of the six identified Air Force RIW programs yielded the experience necessary to consider the individuals knowledgeable of Air Force RIW and, thereby, were qualified under both criteria above. From the selected sample group, identified individuals who met the above criteria were considered qualified to participate in this research.

## Contacting RIW Experts

The next step in the process was to contact those individuals qualified to participate in this research. Initial contact with qualified individuals was by telephone to obtain their approval to participate in this effort.

After obtaining approval to participate in the research effort, and prior to a structured interview, the following two actions were accomplished:

1. Preparation of an information package (Appendix A) which included the purpose of the study, the primary problem/ questions to be analyzed, the expert's role in reaching a solution and the uniqueness of their abilities in the total effort (18:54).

2. Preparation of an interview plan which included the finalization and standardization of the structured interview procedures, and the development of the interview schedule.

Once the information packages were sent to the participating individuals (hereafter identified as the RIW experts), the researchers contacted the RIW experts within one week to insure they received the information and to schedule the structured interviews.

## The Structured Interview

Two means of conducting the structured interview were used. The first means was a personal interview with the RIW experts located at Wright-Patterson AFB, Ohio. Due to cost and time constraints, the second means was through telephone contact with the RIW experts geographically located away from Wright-Patterson AFB. To insure minimum bias between the personal and telephone interviews, a standardized interview format was used.

During the structured interview, the researchers used the following standardized format:

1. Obtain demographic information from the RIW expert.

2. Ascertain complete understanding by the RIW expert of the research problem, the research questions and measurement scales, and the effectiveness criteria.

3. Ask the interview questions and record the RIW expert's ratings of the effectiveness criteria and future recommendation.

4. Conclude with open comments which the RIW expert feels may be pertinent to the research.

## The Interview Instrument

### General

After considering a number of techniques to gather data, the research team determined that a structured interview would yield results desired for this research effort. In making this determination, primary consideration was given to the location of RIW experts, cost and time to collect data. There were several advantages to using a structured interview, including:

1. An interview structured around a list of specific criteria would result in a more meaningful response.

2. Depth and detail of information which could be secured.

3. Quality of information could be improved.

4. Interviewer had more control over the interview.

5. Timeliness and cost-effectiveness.

6. Reduction of nonresponse bias (9:294,305).

Based on these advantages and primary considerations, a combination of personal and telephone interviews was used. With respect to this decision, Emory identified several disadvantages in the use of the personal/telephone interview. These disadvantages included:

1. Limits on the length of the interview.

2. Adverse effects of interviewers who alter the questions asked.

3. Reluctance to talk with strangers (9:294,306).

This research effort insured anonymity of the RIW experts. The purpose of this anonymity was to relieve the RIW experts' concern that candid and honest answers would affect their professional careers (6:43).

Development

In order to obtain the desired information from the RIW experts, the interview instrument was developed in four sections (Appendix B). The first section, General/Demographic, was used for the following two purposes:

1. encourage response and promote rapport, and

2. document the credibility of the RIW experts.

The second section, Program Evaluation, measured the effectiveness of each RIW program as perceived by the RIW experts. In measuring these programs' effectiveness, the RIW experts rated the eleven effectiveness criteria identified in the research effort of Bradney and Perkins (6:34). These researchers suggested that the identified measurement criteria could be incorporated into an evaluation plan for the RIW concept. The criteria identified by Bradney and Perkins, and the associated definitions as applied to this research effort, are found in Table 3-1. Responses to this section were used to answer Research Question One.

The third section, Future Recommendation, indicated the recommendations for future use by the Air Force of the RIW concept, as perceived by the RIW experts. Responses to this section were used to answer Research Question Two.

The fourth and final section of the interview instrument, Open-Ended Questions, consisted of two questions concerning significant subjects of interest to this research team. The questions permitted the RIW experts to respond to questions without the structure imposed by the second section. The research team reviewed and interpreted these open-ended questions to ascertain RIW experts' feelings and expressions of intensity about the RIW concept (9:234). Furthermore, responses to these questions were compared to the results obtained in answering the two Research Questions.

TABLE 3-1

EFFECTIVENESS CRITERIA DEFINED

Reliability - The probability that an item will perform its intended function for a specified interval under stated conditions.

Maintainability - The probability that an item will be restored to a specified condition within a given period of time when proper maintenance is performed.

Acquisition Cost - The total expenditures incurred for the purchase or production of an item.

Equipment Modification (ECN) - Alterations in the physical or functional characteristics of an item after initial establishment of these characteristics.

Data Collection - Collection of required data (R&D, production, training, modification, overhaul, O&M, etc.) during item procurement and support by all levels of management.

Contractor Competition - Competition between responsible, responsive contractors during all phases of item acquisition and support.

Use Rate - The quantity of usage by type that occurs in a specific time period.

Supply System - Organizations, offices, facilities, methods, and techniques necessary to provide an item to authorized users.

Maintenance Skill - Skill required at all maintenance levels to provide proper and adequate item repair.

Number of Spares - Articles identical to or interchangeable with the end item which are procured over and above the quantity needed for initial installation.

RIW Contract Clause - Content necessary to insure that required acquisition and support goals and objectives are established for procurement of an item.

## Testing

Emory states that ". . . once a first draft of the instrument has been developed it must be tested [9:222]." The purpose of this testing was to insure that the instrument used was understandable, unambiguous, clear to both interviewer and interviewee, and concise. The research team used several Air Force officers and civilian personnel with similar backgrounds to the RIW experts to act as interviewees in order to evaluate and provide feedback on the interview instrument. This testing was iterative until only minor problems requiring revision surfaced.

## The Measurement Scales

It was important to be able to quantify the RIW experts' responses in order to answer the research questions. The measurement scales used in the interview instrument were both a seven-point and a three-point Likert scale. The scale for the Program Evaluation section consisted of the following seven possible responses:

1. Least
2. Less
3. Slightly Less
4. Same As
5. Slightly More
6. More
7. Most

The scale for the Future Recommendation section consisted of the following three possible responses:

1. Discontinue
2. Undecided
3. Continue

The Likert scale was selected because of its ease of construction and discriminating ability in respondent-centered research (9:273). Emory states:

> . . . a two-point scale, three-point scale, or scales with more points is a subject which is debated; there is little conclusive support for any particular scale length. One argument is that more points on a scale provide an opportunity for greater sensitivity of measurement. However, the most widely used scales range from three to seven points, and it does not seem to make much difference which number is used [9:261].

As a result, the research team determined that both a seven-point and three-point scale best satisfied the requirements of this research effort.

The Likert scales used resulted in ordinal level data (9:274). Ordinal level data is defined as data which are ranked (least to most) with respect to a measured attribute, but the distance between the ranked items is unknown (23:23-24). According to Emory, ". . . we can report respondents are more or less favorable to a topic, but we cannot tell how much more or less favorable they are [9:274]." The primary attribute measured in this research effort was RIW effectiveness. Thus, this research team reported whether or not RIWs had

been more or less effective, but could not report, to any degree, how much more or less effective RIWs had been.

## Data Analysis Plan

As discussed previously, the data in the Program Evaluation and Future Recommendation sections of the interview instrument were ordinal level data. As such, nonparametric statistical tests were used to perform the statistical analysis. Emory (9:413) suggests that nonparametric tests ". . . are the only technically correct tests to use with ordinal data." Additionally, Harnett says,

> . . . to avoid the parametric assumptions normally required for tests based on ratio and interval scales, most nonparametric tests assume only nominal or ordinal data [12:695].

For these reasons, statistical analysis of the Program Evaluation and Future Recommendation sections were justified using nonparametric tests. Analysis of the General/Demographic information of the interview instrument was descriptive in nature and presented in tabular form. In the last section of the interview instrument, analysis of the open-ended questions consisted of a qualitative evaluation by the research team to compare these responses to the information in the Program Evaluation and Future Recommendation sections. The research questions and supporting qualitative research hypotheses that comprised this research effort's methodology are restated:

Research Question One. What are the perceptions of active duty Air Force officers and DOD civilians with Air Force RIW expertise regarding the effectiveness of RIWs as applied to Air Force programs since August 1974?

Supporting Qualitative Research (Null) Hypotheses for Research Question One.

1-6. Active duty Air Force officers and DOD civilians with Air Force RIW expertise perceive the

(1) AN/ARN 118 TACAN

(2) C-141 AHRS

(3) OMEGA Nav Set

(4) Carousel IV INS

(5) F-16 Electronic Components

(6) Air Force Standard INU

RIW program as ineffective (this represents one hypothesis for each of the six Air Force RIW programs).

7. Active duty Air Force officers and DOD civilians with Air Force RIW expertise perceive the Air Force RIW program as ineffective.

Research Question Two. What is the recommendation for the future use by the Air Force of the RIW concept, as perceived by Air Force officers and DOD civilians with Air Force RIW expertise?

Supporting Qualitative Research (Null) Hypothesis for Research Question Two.

8. Active duty Air Force officers and DOD civilians with Air Force RIW expertise do not recommend the continued use by the Air Force of the RIW concept.

## Statistical Methodology

The most appropriate statistic of central tendency in an ordinal scale is the median, since the median is ". . . not affected by changes of any scores which are above or below it as long as the number of scores above and below remains the same [23:25]." Harnett defines the median, ". . . as the middle value in a set of numbers arranged in order of magnitude [12:15]." If the total number of values in the data set is odd, the median is the middle of the data set (12:15). If the total number of values in the data set is even, the median is the average of the two middle values of the data set (12:15). Throughout this research effort, the median was used to evaluate the research questions and hypotheses presented earlier.

To use the median, the arabic numerical scales (i.e., 1-7 and 1-3 inclusive), associated with the two Likert scales in the interview instrument was used. The purpose of these arabic numerical scales was to calculate the numerical medians.

The technique used to evaluate (measure) perceived effectiveness of the Air Force RIW program and to evaluate the perceived recommendation for future use by the Air Force of the RIW concept involved the RIW expert's individual ratings. Research Hypothesis One through Six was evaluated using the set of RIW expert's individual ratings for each Air Force RIW program; and Research Hypotheses Seven and Eight were evaluated using the set of all the RIW expert's individual ratings.

Prior to conducting nonparametric tests associated with Research Hypotheses One through Eight to evaluate the two research questions, the use of contingency table analysis or other validating means was not required to validate the RIW experts' effectiveness criteria ratings. In this research effort, the RIW experts' ratings were assumed a valid measure of perceived effectiveness of Air Force RIWs. While validation of RIW experts' ratings was not required, further definition of these ratings was required before statistical analysis.

To further define the RIW experts' effectiveness criteria ratings, a rating of four (4) on the seven-point scale, previously discussed, was selected as the neutral rating. This neutral rating is the division between an effective and ineffective rating. Therefore, for the effectiveness criteria of Reliability, Maintainability, Contractor

Competition, Use Rate or RIW Contract Clause a rating greater than four indicated RIW effectiveness; whereas, a rating of less than or equal to four indicated RIW effectiveness. For the effectiveness criteria of Acquisition Cost, Equipment Modification, Data Collection, Supply System, Maintenance Skill or Number of Spares, a rating of less than four indicated RIW effectiveness; whereas, a rating of greater than or equal to four indicated RIW ineffectiveness. Table 3-2 illustrates the definition of RIW experts' ratings. To facilitate statistical analysis, the RIW experts' ratings of the effectiveness criteria of Acquisition Cost, Equipment Modification, Data Collection, Supply System, Maintenance Skill and Number of Spares was recoded to insure consistency of experts' ratings. For example, if an RIW expert rated Acquisition Cost as two (2), this criterion was recoded as six (6), which implies the same level of effectiveness. Therefore, after recoding, for all eleven effectiveness criteria a rating greater than four indicated RIW effectiveness; whereas, a rating less than or equal to four indicated RIW ineffectiveness. Table 3-3 illustrates the recoding of RIW experts' ratings.

Following further definition and recoding of the RIW experts' criteria ratings, the eight supporting qualitative research hypotheses used in conjunction with the two research questions were individually evaluated. In evaluating these

TABLE 3-2

DEFINITION OF RIW EXPERTS' RATINGS

| If the Effectiveness Criterion is | and if the rating is $>4$, the RIW is | or if the rating is $<4$, the RIW is | or if the rating is $=4$, the RIW is |
|---|---|---|---|
| Reliability | Effective | Ineffective | Ineffective |
| Maintainability | Effective | Ineffective | Ineffective |
| Acquisition Cost | Ineffective | Effective | Ineffective |
| Equipment Modification | Ineffective | Effective | Ineffective |
| Data Collection | Ineffective | Effective | Ineffective |
| Contractor Competition | Effective | Ineffective | Ineffective |
| Use Rate | Effective | Ineffective | Ineffective |
| Supply System | Ineffective | Effective | Ineffective |
| Maintenance Skill | Ineffective | Effective | Ineffective |
| Number of Spares | Ineffective | Effective | Ineffective |
| RIW Contract Clause | Effective | Ineffective | Ineffective |

TABLE 3-3

RECODED RIW EXPERTS' RATINGS

| If the RIW Experts' Rating for the Effectiveness Criteria of Acquisition Cost, Equipment Modification, Data Collection, Supply System, Maintenance Skill or Number of Spares is | Then the RIW Experts' Rating is Recoded as a Rating of |
|---|---|
| 1 | 7 |
| 2 | 6 |
| 3 | 5 |
| 4 | 4 |
| 5 | 3 |
| 6 | 2 |
| 7 | 1 |

hypotheses, the following five-step procedure of hypothesis testing (12:351) was considered:

1. State the null ($H_O$) and alternative ($H_A$) hypotheses;

2. Determine the appropriate test statistic;

3. Determine the critical region;

4. Compute the value of the test statistic; and

5. Make the statistical decision and interpretation.

The statistical equivalent $H_O$ and $H_A$ for each of the Research Hypotheses One through Six was:

$H_O$: The median RIW experts' individual ratings on all eleven effectiveness criteria on the

(1) AN/ARN 118 TACAN

(2) C-141 AHRS

(3) OMEGA Nav Set

(4) Carousel IV INS

(5) F-16 Electronic Components

(6) Air Force Standard INU

RIW programs $\leq$ 4 (i.e., the neutral rating)

$H_A$: The median RIW experts' individual ratings on all eleven effectiveness criteria on the

(1) AN/ARN 118 TACAN

(2) C-141 AHRS

(3) OMEGA Nav Set

(4) Carousel IV INS

(5) F-16 Electronic Components

(6) Air Force Standard INU

RIW program > 4.

$\alpha = .05$

By rejecting any of the six $H_O$'s, the research team would have concluded that the RIW experts perceive the RIW, with respect to that Air Force program as effective. By accepting any of the six $H_O$'s, the research team would have concluded that the RIW experts perceive the RIW, with respect to that Air Force RIW program, as ineffective.

After Research Hypotheses One through Six were tested to determine individual program effectiveness or ineffectiveness, two statistical tests were developed to test Research Hypothesis Seven. First, a statistical test was developed to simply determine whether a significant percentage of the Air Force RIW programs were effective. The statistical equivalent $H_O$ and $H_A$ for the first test of Research Hypothesis Seven was:

$H_O$: The proportion of effective Air Force AIR programs $\leq 0.5$

$H_A$: The proportion of effective Air Force RIW programs $> 0.5$

$\alpha = .15$

By rejecting $H_O$, the research team would have concluded that the RIW experts perceive the overall Air Force RIW program as effective. By accepting $H_O$, the research team would have

concluded that the RIW experts perceive the overall Air Force RIW program as ineffective. This first statistical test alone would be somewhat restrictive with $\alpha = .05$ level, all six Air Force RIW programs would have to be effective (i.e., using the Binomial Test with proportion = 0.5, the probability of six effective programs is .016 and the probability of at least five effective programs is .11; therefore, at $\alpha = .05$, $H_O$ would only be rejected for six effective programs). To be less restrictive, the significance level was, therefore, reduced to $\alpha = .15$, thus requiring only five of the six Air Force RIW programs to be effective before $H_O$ is rejected. To compensate for the reduced significance level, a second statistical test was constructed using the set of <u>all</u> the RIW experts' individual ratings. The statistical equivalent $H_O$ and $H_A$ for the second test of Research Hypothesis Seven was:

$H_O$: The median RIW experts' individual ratings on all eleven effectiveness criteria on all six Air Force RIW programs $\leq 4$.

$H_A$: The median RIW experts' individual ratings on all eleven effectiveness criteria on all six Air Force RIW programs $> 4$.

$\alpha = .05$

By rejecting $H_O$, the research team would have concluded that the RIW experts perceive the overall Air Force RIW program as

effective. By accepting $H_O$, the research team would have concluded that the RIW experts perceive the overall Air Force program as ineffective.. Finally, by rejecting $H_O$ on both statistical tests for Research Hypothesis Seven, the research team would have concluded that the RIW experts perceive the overall Air Force RIW program as effective. Therefore, by accepting $H_O$ on one or both statistical tests for Research Hypothesis Seven, the research team would have concluded that the RIW experts perceive the overall Air Force program as ineffective.

The null and alternative hypotheses for Research Question Two were developed in two phases, with phase two dependent on the results in phase one. The statistical equivalent $H_O$ and $H_A$ for phase one of Research Hypothesis Eight was:

$H_O$: The median RIW experts' ratings on the future use by the Air Force of the RIW concept = 2.

$H_A$: The median RIW experts' ratings on the future use by the Air Force of the RIW concept is $\neq 2$.

$\alpha = .05$

By accepting $H_O$, the research team would have concluded that the RIW experts are undecided on the future use by the Air Force of the RIW concept. Therefore, phase two of Research Hypothesis Eight would not be required. By rejecting $H_O$, the research team would have concluded that the RIW experts are

decided on the future use by the Air Force of the RIW concept. Therefore, phase two of Research Hypothesis Eight would be required to determine the RIW experts' recommendation on the future use by the Air Force of the RIW concept. The RIW experts' recommendation was determined by the majority of positive or negative signed ranks of the statistical test. The sign and quantity of the ranks of the statistical test indicated on which side of the median the majority of the distribution lies. If the signed ranks are positive (+), this indicates the RIW experts' ratings are greater than the median (2); and if the signed ranks are negative (-), this indicates the RIW experts' ratings are less than the median (2). Therefore, if the majority of signed ranks are positive, the research team would have concluded that the RIW experts recommend continued use by the Air Force of the RIW concept; and if the majority of signed ranks are negative, the research team would have concluded that the RIW experts do not recommend continued use by the Air Force of the RIW concept.

The statistical test used for Research Hypotheses One through Six was the Wilcoxon Matched-Pairs Signed-Ranks Test (23:75-83). This statistical test enabled the research team to compare RIW experts' individual ratings to a neutral rating to determine whether the RIW experts perceive each of the six Air Force programs to be effective. The statistical tests used for Research Hypothesis Seven were a Binomial

Test (23:36-42) and the Wilcoxon Matched-Pairs Signed-Ranks Test (23:75-83). These statistical tests enabled the research team to determine the effectiveness of the overall Air Force RIW program as perceived by the RIW experts. The statistical test used for Research Hypothesis Eight was the Wilcoxon Matched-Pairs Signed-Ranks Test (23:75-83). This statistical test enabled the research team to compare RIW experts' individual ratings to a neutral rating to determine the RIW experts' recommendation for the future use by the Air Force of the RIW concept.

## Assumptions and Limitations

In this research project, this research team made several assumptions and identified the scope and limitations. These assumptions were categorized as statistical assumptions and general assumptions. Both categories of assumptions and the identified scope and limitations were necessary for research consistency, and are detailed below.

### Statistical Assumptions

1. The use of the seven-point and three-point Likert scales in the interview instrument resulted in ordinal level data.

2. The use of nonparametric statistics was justified due to the unknown population distributions from which the sample was drawn.

3. Nonparametric techniques provided statistical analysis of ordinal level data.

4. The purposive sampling method was a valid technique for developing a sample for nonparametric testing.

## General Assumptions

1. Each RIW expert's effectiveness criteria ratings were a valid measure of perceived effectiveness of Air Force RIWs.

2. The RIW experts provided honest responses and took a reasonable amount of time to consider responses to each criterion of the interview instrument.

3. The interview instrument was a reliable attitude measurement tool that was adequately tested.

4. The research team's definition of effectiveness was appropriate for this research effort.

5. The RIW effectiveness criteria identified by previous research was appropriate and valid for this research effort.

6. Two years in program management, contracting management, or logistics management, on any of the six Air Force RIW programs, yielded the experience necessary to consider individuals knowledgeable of Air Force RIWs.

## Scope and Limitations

1. Individuals with Air Force RIW expertise were limited to active duty Air Force officers and DOD civilians.

2. Only those Air Force RIW programs previously identified were included in this research effort.

3. The conclusions of this research effort applied only to the RIW experts identified earlier in this chapter.

4. The measurement of RIW experts' perceptions were qualitative in nature.

5. The answers to the open-ended questions were reviewed and interpreted by the research team and conclusions were based on the team's subjective judgment.

## Summary

Chapter I described the need for determining RIW effectiveness, defined the research problem, and identified research objectives. Chapter II provided background and discussed the origins of Reliability Improvement Warranties, the use of RIWs by DOD, and the development of the Air Force RIW program from its inception to the present day. This chapter described the methodology to be used by the research team to evaluate the effectiveness of the Air Force RIW program. Using this methodology, the research team analyzed the data in Chapter IV.

## CHAPTER IV

## DATA ANALYSIS

### Introduction

The purpose of the Data Analysis Chapter is to present and analyze the interview data using the research methodology developed in Chapter III. This chapter includes (1) a descriptive tabular analysis of the General/Demographic information, (2) analysis of the two research questions presented in Chapter I, and (3) a qualitative evaluation of the open-ended interview questions. Analysis of the two research questions consists of nonparametric statistical tests.

### General/Demographic Information

The RIW experts, as identified in Chapter III, were those individuals who

1. have a basic knowledge of the problem area and are able to apply that knowledge;

2. have experience formulating, implementing or monitoring an Air Force RIW program; and

3. have two or more years experience in program management, contract management, or logistics management on any of the six Air Force RIW programs.

The following tables describe the general characteristics of the RIW experts. Inferences concerning the RIW

experts are neither implied nor attempted for the entire population of active duty Air Force officers and DOD civilians previously or currently involved in one of the six Air Force RIW programs.

Table 4-1 illustrates Air Force officer and DOD civilian RIW experts by general career field. A majority (21 of 36 or 58.3 percent) of the RIW experts have logistics management career field experience. The RIW experts with program management (10 of 36) and contract management (5 of 36) experience constitute 27.8 percent and 13.9 percent, respectively.

TABLE 4-1

RIW EXPERTS BY GENERAL CAREER FIELD

| General Career Field | Air Force Officers | Per-cent | DOD Civilians | Per-cent | Total |
|---|---|---|---|---|---|
| Program Management | 7 | 100 | 3 | 10.3 | 10 |
| Contract Management | 0 | 0 | 5 | 17.2 | 5 |
| Logistics Management | 0 | 0 | 21 | 72.5 | 21 |
| Total | 7 | 100 | 29 | 100.0 | 36 |

Table 4-2 lists the Air Force RIW program by general career field. For each RIW program, the greatest number of RIW experts have logistics management experience.

TABLE 4-2

RIW PROGRAM BY GENERAL CAREER FIELD

| General Career Field | TACAN | AHRS | OMEGA | C-IV | F-16 | AF St INU |
|---|---|---|---|---|---|---|
| Program Management | 2 | 2 | 1 | 1 | 2 | 2 |
| Contract Management | 1 | 0 | 3 | 0 | 1 | 0 |
| Logistics Management | 3 | 3 | 3 | 4 | 4 | 4 |
| Total | 6 | 5 | 7 | 5 | 7 | 6 |

Table 4-3 illustrates the years of experience by general career field. The overall average years of experience of the RIW experts is 16.4 years.

TABLE 4-3

YEARS OF EXPERIENCE BY GENERAL CAREER FIELD

| General Career Field | Cumulative Yrs Experience | Average Yrs Experience |
|---|---|---|
| Program Management | 87 | 8.7 |
| Contract Management | 88 | 17.6 |
| Logistics Management | 414 | 19.7 |
| Total | 589 | 16.4 |

Table 4-4 lists the RIW experts by specific Air Force Specialty Code (AFSC)/Civilian Job Series. A plurality (38.9 percent) of the RIW experts possess a 346 job series (Logistics Management Specialist).

TABLE 4-4

RIW EXPERTS BY SPECIFIC
AFSC/JOB SERIES

| AFSC/Job Series | Program Mgmt | Contract Mgmt | Logistics Mgmt | Percent |
|---|---|---|---|---|
| 301 | 1 | | | 2.8 |
| 346 | | | 14 | 38.9 |
| 800 | 2 | | 3 | 13.8 |
| 856 | | | 1 | 2.8 |
| 1102 | | 4 | | 11.1 |
| 1105 | | 1 | | 2.8 |
| 1670 | | | 2 | 5.6 |
| 27XX | 4 | | | 11.1 |
| 28XX | 2 | | 1 | [illegible].3 |
| 66XX | 1 | | | 2.8 |
| Total | 10 | 5 | 21 | 100.0 |

Table 4-5 illustrates the years of RIW experience by general career field. The overall average years of RIW experience of the RIW experts (152 cumulative years of RIW experience divided by the 36 RIW experts) is 4.2 years.

TABLE 4-5

YEARS OF RIW EXPERIENCE BY GENERAL CAREER FIELD

| General Career Field | Cumulative Yrs Experience | Average Yrs Experience |
|---|---|---|
| Program Management | 33 | 3.3 |
| Contract Management | 22 | 4.4 |
| Logistics Management | 97 | 4.6 |
| Total | 152 | 4.2 |

Table 4-6 lists years of RIW experience per RIW expert for each of the six Air Force RIW programs. As an example, the third RIW expert on the C-141 AHRS program had five years of RIW experience, whereas the fourth RIW expert on that program had two years of RIW experience. Of the RIW experts interviewed, the greatest number of years of RIW experience is on the F-16 program.

TABLE 4-6

YEARS OF RIW EXPERIENCE BY PROGRAM

| Program | Years of RIW Experience Per Expert | | | | | | | Cumulative Years of RIW Experience |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| ARN 118 TACAN | 2 | 5 | 5 | 6 | 5 | 6 | - | 29 |
| C-141 AHRS | 5 | 3 | 5 | 2 | 3 | - | - | 18 |
| OMEGA Nav Set | 5 | 5 | 3 | 3 | 3 | 4 | 3 | 26 |
| C-IV INS | 5 | 5 | 4 | 4 | 4 | - | - | 22 |
| F-16 Elex | 2 | 3 | 7 | 4 | 7 | 6 | 7 | 36 |
| AF St INU | 5 | 3 | 3 | 3 | 4 | 5 | - | 23 |

## Program Evaluation

### Research Question One

What are the perceptions of active duty Air Force officers and DOD civilians with Air Force RIW expertise regarding the effectiveness of RIWs applied to Air Force programs since 1974? Seven supporting qualitative research hypotheses were used to answer Research Question One:

1. Research (Null) Hypotheses One through Six: Active duty Air Force officers and DOD civilians with Air Force RIW expertise perceive the

   (1) AN/ARN 118 TACAN

   (2) C-141 AHRS

   (3) OMEGA Nav Set

   (4) Carousel IV INS

   (5) F-16 Electronic Components

   (6) Air Force Standard INU

   RIW program as ineffective.

   a. Statistical Test: Wilcoxon Matched-Pairs Signed-Ranks Test, $\alpha = .05$. The statistical equivalent $H_O$ and $H_A$ for each of the Research Hypotheses One through Six are:

      $H_O$: The median RIW experts' individual ratings on all eleven effectiveness criteria on the

(1) AN/ARN 118 TACAN

(2) C-141 AHRS

(3) OMEGA Nav Set

(4) Carousel IV INS

(5) F-16 Electronic Components

(6) Air Force Standard INU

RIW program $\leq$ 4.

$H_A$: The median RIW experts' individual ratings on all eleven effectiveness criteria on the

(1) AN/ARN 118 TACAN

(2) C-141 AHRS

(3) OMEGA Nav Set

(4) Carousel IV INS

(5) F-16 Electronic Components

(6) Air Force Standard INU

RIW program > 4.

Because this was a one-tailed statistical test, the decision to reject $H_O$ was determined if one-half the calculated two-tailed probability was less than the significance level chosen, $\alpha = .05$. The null hypothesis is rejected if the calculated z-statistic has a probability less than the specified alpha level (15:228).

b. Results: Appendix C, Tables C-1 through C-6 illustrate results of the Wilcoxon Matched-Pairs Signed-Ranks Test for the RIW experts on each of the six Air Force RIW programs. On the AN/ARN 118 TACAN RIW program, one-half the calculated two-tailed probability was .0155, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected $H_O$ and were 95 percent confident that the RIW experts perceived the AN/ARN 118 TACAN RIW program as effective. On the C-141 AHRS RIW program, one-half the calculated two-tailed probability was .0005, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected $H_O$ and were 95 percent confident that the RIW experts perceived the C-141 AHRS RIW program as effective. On the OMEGA Nav Set RIW program, one-half the calculated two-tailed probability was .0165, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected $H_O$ and were 95 percent confident that the RIW experts perceived the OMEGA Nav Set RIW program as

effective. On the Carousel IV INS RIW program, one-half the calculated two-tailed probability was .0055, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected $H_O$ and were 95 percent confident that the RIW experts perceived the Carousel IV INS RIW program as effective. On the F-16 Electronic Components RIW program, one-half the calculated two-tailed probability was .005, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected $H_O$ and were 95 percent confident that the RIW experts perceived the F-16 Electronic Components program as effective. On the Air Force Standard INU RIW program, one-half the calculated two-tailed probability was .0005, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected $H_O$ and were 95 percent confident that the RIW experts perceived the Air Force Standard INU program as effective.

2. Research (Null) Hypothesis Seven: Active duty Air Force officers and DOD civilians with Air Force RIW expertise perceive the Air Force RIW program as ineffective.

a. Statistical Test One: Binomial Test, $\alpha = .15$. The statistical $H_O$ and $H_A$ for the first test of Research Hypothesis Seven are:

$H_O$: The proportion of effective Air Force RIW programs $\leq .05$.

$H_A$: The proportion of effective Air Force RIW programs $> .05$.

Since this was a one-tailed statistical test, the decision to reject $H_O$ was determined if the calculated one-tailed probability was less than the significance level chosen, $\alpha = .15$.

b. Statistical Test Two: Wilcoxon Matched-Pairs Signed-Ranks Test, $\alpha = .05$. The statistical equivalent $H_O$ and $H_A$ for the second test of Research Hypothesis Seven are:

$H_O$: The median RIW experts' individual ratings on all eleven effectiveness criteria on all six Air Force RIW programs $\leq 4$.

$H_A$: The median RIW experts' individual ratings on all eleven effectiveness criteria on all six Air Force RIW programs $> 4$.

Because this was a one-tailed statistical test, the decision to reject $H_O$ was determined

if one-half the calculated two-tailed probability was less than the significance level chosen, $\alpha = .05$.

c. <u>Results</u>: Appendix C, Tables C-7 and C-8 illustrate the results of the Binomial Test and the Wilcoxon Matched-Pairs Signed-Ranks Test for the RIW experts on all six of the Air Force RIW programs. From the Binomial Test, the calculated one-tailed probability was .016, which was less than the significance level of $\alpha = .15$. Therefore, the research team rejected the first $H_0$ and were 85 percent confident that the RIW experts perceived the overall Air Force RIW program as effective. From the Wilcoxon Test, one-half the calculated two-tailed probability was .000, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected the second $H_0$ and were 95 percent confident that the RIW experts perceived the overall Air Force RIW program as effective. By rejecting $H_0$ on <u>both</u> statistical tests for Research Hypothesis Seven, the research team concluded that the RIW experts perceive the overall Air Force RIW program as effective.

## Future Recommendation

### Research Question Two

What is the recommendation for the future use by the Air Force of the RIW concept, as perceived by Air Force officers and DOD civilians with Air Force RIW expertise? One supporting qualitative research hypothesis was used to answer Research Question Two:

1. Research (Null) Hypothesis Eight: Active duty Air Force officers and DOD civilians with Air Force RIW expertise do not recommend the continued use by the Air Force of the RIW concept.

   a. Statistical Test: Wilcoxon Matched-Pairs Signed-Ranks Test, $\alpha = .05$. The statistical equivalent $H_O$ and $H_A$ for phase one of Research Hypothesis Eight are:

      $H_O$: The median RIW experts' ratings on the future use by the Air Force of the RIW concept = 2.

      $H_A$: The median RIW experts' ratings on the future use by the Air Force of the RIW concept $\neq$ 2.

   Since this is a two-tailed statistical test, the decision to reject $H_O$ was determined if the calculated two-tailed probability was less than the significance level chosen, $\alpha = .05$.

b. Results: Appendix C, Table C-9 illustrates results of the Wilcoxon Matched-Pairs Signed-Ranks Test for the RIW experts on the future use by the Air Force of the RIW concept. The calculated two-tailed probability was .000, which was less than the significance level of $\alpha = .05$. Therefore, the research team rejected $H_0$ and were 95 percent confident that the RIW experts were decided on the future use by the Air Force of the RIW concept. Appendix C, Table C-9 illustrates that the majority of the signed ranks are positive (30 +Ranks compared to 1 -Rank). The research team concluded that the RIW experts recommend continued use by the Air Force of the RIW concept.

## Open-Ended Questions

The fourth section of the interview instrument, Open-Ended Questions (see Appendix B), contained two questions which afforded the RIW experts an opportunity to comment on their RIW programs, and to comment on their recommendation for future use by the Air Force of the RIW concept.

To ascertain RIW experts' feelings and expressions of intensity about the RIW concept, the research team reviewed and interpreted the two open-ended questions.

Appendix D, Tables D-1 and D-2, contains all the RIW experts' responses to these open-ended questions. With respect to the first open-ended question, the following is the research team's review and interpretation of the RIW experts' comments by RIW program:

1. <u>AN/ARN 118 TACAN</u>. The majority of comments indicated possible deficiencies with the use of RIW early in program development. These deficiencies were indicated by comments such as "the AN/ARN 118 was not a good choice for RIW," "reliability was already built-in," and "the RIW drove out other competitors."

2. <u>C-141 AHRS</u>. Comments on this program indicated problems in the management of the RIW. These problems were supported by comments such as "accurate MTBFs could not be determined," and "the 66-1 Maintenance Data Collection didn't work."

3. <u>OMEGA Nav Set</u>. Comments such as "the RIW enhanced availability," OMEGA was a good choice for RIW," and "the RIW provided the contractor flexibility to make money in the short term so the Air Force could gain benefits in the long term" indicated that the implementation and use of RIW on this program was positive.

4. <u>Carousel IV INS</u>. Comments on this program, such as "the RIW was more effective getting reliability into the

system," and "the contractor had high confidence in reliability improvement" illustrated the successful application of RIW.

5. F-16 Electronic Components. Comments on this program indicated the use of RIW was very successful with respect to system cost and Interim Contractor Support (ICS) cost avoidance. These comments were "the price paid for the RIW was $50 - $100 million less than non-RIW," "cost-effectiveness analysis indicated $100 million savings with the RIW," and "F-16 RIW regarded successful, mostly due to ICS cost avoidance."

6. Air Force Standard INU. "Compared to the non-RIW INU on the F-15, the Standard INU reliability increased 350 percent," and "no-cost ECPs forced reliability growth in the first two years" are comments which illustrate successful application of RIW on this program.

Regarding the second open-ended question, the research team's review and interpretation found that the majority of the RIW experts' comments recommend continued use of the RIW concept as well as various recommendations for improving the concept. Appendix D, Table D-2, contains these RIW experts' recommendations.

## Summary

The Data Analysis Chapter established that the RIW experts were knowledgeable and experienced (16.4 years of)

management experience) individuals, each with an average of 4.2 years of RIW experience. Nonparametric statistical tests were used to analyze the two research questions in Chapter I. Finally, the research team was able to identify key observations from RIW experts' comments to the open-ended questions. In the final chapter that follows, the research team provides conclusions and recommendations from this research effort.

CHAPTER V

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## Introduction

The purpose of this chapter is to present the results of the research team's effort. First, the research team will restate the research objectives and questions from Chapter I and summarize the methodology used in this research effort. Second, the research team will present several conclusions drawn from the research effort. Finally, recommendations for future follow-on research efforts and research observations relating to the Air Force RIW program will be identified.

## Research Design Summary

The two research objectives and questions identified in Chapter I established the basic framework for this research effort:

### Research Objectives

1. To determine if RIWs applied to Air Force programs since August 1974 were effective.

2. To recommend the future use by the Air Force of the RIW concept.

Research Questions

1. What are the perceptions of active duty Air Force officers and DOD civilians with Air Force RIW expertise regarding the effectiveness of RIWs as applied to Air Force programs since August 1974?

2. What is the recommendation for the future use by the Air Force of the RIW concept as perceived by Air Force officers and DOD civilians with Air Force RIW expertise?

Data were collected by means of personal/telephone interviews with the identified RIW experts. The research team analyzed the data in accordance with the research methodology described in Chapter III. The main points of the research team's methodology included:

1. Selection and interview of RIW experts.

2. Definition and recoding of RIW experts' ratings of the eleven effectiveness criteria.

3. Nonparametric statistical tests used to answer Research Question One which consisted of:

a. The Wilcoxon Matched-Pairs Signed-Ranks Test performed on RIW experts' median ratings of the effectiveness criteria.

b. The Binomial Test performed on the overall ratings of each of the six Air Force RIW programs.

4. Nonparametric statistical tests used to answer Research Question Two which consisted of the Wilcoxon

Matched-Pairs Signed-Ranks Test performed using RIW experts' recommendation for the future use by the Air Force of the RIW concept.

5. Six numerical tables that presented general/demographic information on the RIW experts.

6. Review and interpretation of RIW experts' responses to the two open-ended questions.

## Conclusions

The final conclusions of this research effort are presented in four sections: General/Demographic, Program Evaluation, Future Recommendation and Open-Ended Questions. The General/Demographic section contains information about RIW experts' career areas and experience levels. The Program Evaluation and Future Recommendation sections address Research Question One and Two, respectively. Finally, the Open-Ended Questions section of this chapter provides additional feedback from the RIW experts who have knowledge and expertise in formulating, implementing and monitoring Reliability Improvement Warranties.

Before accepting the conclusion of this research effort, the reader should review the assumptions and scope and limitations presented in Chapter III. Further, it should be noted that the conclusions apply to the group of thirty-six RIW experts who participated in this research effort.

The research team did not attempt to infer or imply to any overall population.

General/Demographic

A summary of the research team's conclusions relating to the demographic/general profiles of RIW experts are listed below:

1. The research team concluded that the majority (72.5 percent) of RIW experts come from the general career field of logistics management. For this research effort, this fact shows that RIW management is emphasized in the logistics area.

2. The combined experience level for all RIW experts in their respective career fields is 16.4 years. However, of the three general career fields, program management had the least average number of years experience (8.7 years).

3. Seventy percent of the RIW experts with program management experience were active duty Air Force officers. One-hundred percent of the RIW experts with contract or logistics management experience were DOD civilians.

4. The combined RIW experience level for all RIW experts in their respective career fields is 4.2 years. This is twice the number of years assumed necessary to quality as a RIW expert.

5. On the average, RIW experts on each of the six Air Force RIW programs had 25.7 years of cumulative RIW experience.

Program Evaluation

A summary list of the RIW experts' evaluations of the overall effectiveness of the Air Force RIW program is provided below:

1. The RIW experts, on each of the six Air Force RIW programs, perceived that the use of the RIW on their respective program was effective. This conclusion was statistically supported by the results of the Wilcoxon Matched-Pairs Signed-Ranks Test discussed in Chapter IV.

2. Based on the perceived effectiveness of each of the six Air Force RIW programs, the RIW experts perceived that the overall Air Force RIW program was effective. This conclusion was statistically supported by the results of the Binomial Test and Wilcoxon Matched-Pairs Signed-Ranks Test described in Chapter IV.

Future Recommendation

The research team concludes that the RIW experts recommended the continued use by the Air Force of the RIW concept. This conclusion is statistically supported by the results of the Wilcoxon Matched-Pairs Signed-Ranks Test described in Chapter IV.

## Open-Ended Questions

A summary list of the research team's conclusions is provided below:

1. Although the RIW experts perceived each of the six Air Force RIW programs as effective, numerous problems with the use of RIW were identified.

2. When applied effectively, RIWs can be used as successful contracting incentives both in the acquisition and support of Air Force systems.

3. For the RIW concept to be successfully continued, the RIW must be better managed--the right system needs to be selected for RIW application, accurate and sufficient data on the system needs to be collected, and a definitive contract with a specific RIW clause needs to be applied to the system.

## Recommendations for Future Research

The research team suggests the following recommendations for future research in descending order of importance:

1. Replicate this project using industry's RIW experts on each of the six Air Force RIW programs.

2. For RIW management purposes, this research effort should be replicated within the next five years to evaluate those new programs with RIWs.

3. A parallel research effort should be performed to measure the effectiveness of the Army and Navy's RIW program as perceived by RIW experts.

4. Perform a parallel project using any of the other Air Force Product Performance Agreements (PPA) to measure the effectiveness of that agreement as perceived by that agreement's experts.

5. Design a research project to develop a standardized data base system or management information system for Air Force RIW management.

6. A research project should be conducted to compare similar systems with and without a RIW.

## Research Observations

As a result of this research effort, the research team has shown that Reliability Improvement Warranties applied to Air Force programs during the trial period were effective. Additionally, this research effort indicated that the use of the Air Force RIW contracting concept should be continued. Of practical value, this research effort provided Air Force management the following:

1. Real-time feedback from RIW experts regarding RIW program effectiveness.

2. An assessment of the Air Force RIW trial period.

3. Justification for continued use by the Air Force of the RIW concept.

# APPENDICES

APPENDIX A

INTERVIEWEE INFORMATION PACKAGE

**DEPARTMENT OF THE AIR FORCE**
**AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)**
**WRIGHT-PATTERSON AIR FORCE BASE, OH 45433**

5 May 1983

REPLY TO ATTN OF: LSQ (LSSR 58-83/Capts D. Parkinson and A. Schoolcraft/AV 785-6569

SUBJECT: Thesis Research - Effectiveness of Reliability Improvement Warranties (RIW)

TO:

1. The purpose of this letter is to thank you for your willingness to participate in this research, and to provide you preliminary information prior to your interview with the research team.

2. You have been identified by the research team, and by your peers, as having knowledge of RIWs as applied to specific Air Force programs. Your knowledge and experience provided during the interview are very important to this research project. Your responses will be kept anonymous, both within the group of interviewees and in the report.

3. Attachment 1 provides additional information about this research project, your participation in the research, and your preparation for the interview. This information will give you time to prepare for the interview as well as reduce the length of the interview.

4. Captains Parkinson and Schoolcraft look forward to meeting with you. They will be contacting you within a week to schedule a mutually convenient time for the interview.

Theodore J. Novak Jr.

THEODORE J. NOVAK, Jr., Lt Col, USAF
Head, Dept of Cost Analysis and Pricing
School of Systems and Logistics

1 Atch
Interviewee Information

AIR FORCE—A GREAT WAY OF LIFE

## INTERVIEWEE INFORMATION

The position you hold (or held) within your program identifies you to be among the most knowledgeable individuals with Air Force RIW experience. We believe that your responses will help us analyze the impact RIWs have had during the Air Force RIW trial period.

The purpose of this research is to evaluate the effectiveness of RIWs applied to Air Force programs since 1974, and to make recommendations as to the future use of the Air Force RIW concept.

During the interview, you will be asked to rate your program (see Atch 1-2) against each of the effectiveness criteria defined in Atch 1-3.

By providing this information prior to the interview, we feel you can briefly review these criteria and your program, and thus be better prepared to evaluate your program's RIW during the actual interview.

We expect the interview to last no more than 15-20 minutes. After completion of the structured interview, feel free to provide open comments about your program. If you have any questions prior to the interview, please call either of the researchers.

Atch 1-1

PROGRAM RATING

With respect to your RIW program, please use the following scale and question to rate each of the effectiveness criteria.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| LEAST | LESS | SLIGHTLY LESS | SAME AS | SLIGHTLY MORE | MORE | MOST |

Question: Based on your experience and expertise, how would you rate your program with RIW compared to similar programs without RIW?

_____ Reliability

_____ Maintainability

_____ Acquisition cost

_____ Equipment modification

_____ Data collection

_____ Contractor competition

_____ Use rate

_____ Supply system

_____ Maintenance skill

_____ Number of spares

_____ RIW contract clause

Atch 1-2

## EFFECTIVENESS CRITERIA DEFINED

Reliability - the probability that an item will perform its intended function for a specified interval under stated conditions.

Maintainability - the probability that an item will be restored to a specified condition within a given period of time when proper maintenance is performed.

Acquisition cost - the total expenditures incurred for the purchase or production of an item.

Equipment modification (ECN) - alterations in the physical or functional characteristics of an item after initial establishment of these characteristics.

Data collection - collection of required data (R&D, production, training, modification, overhaul, O&M, etc.) during item procurement and support by all levels of management.

Contractor competition - competition between responsible, responsive contractors during all phases of item acquisition and support.

Use rate - the quantity of usage by type that occurs in a specific time period.

Supply system - organizations, .fices, facilities, methods, and techniques necessary to provide an item to authorized users.

Maintenance skill - skill required at all maintenance levels to provide proper and adequate item repair.

Number of spares - articles identical to or interchangeable with the end item which are procured over and above the quantity needed for initial installation.

RIW Contract clause - content necessary to insure that required acquisition and support goals and objectives are established for procurement of an item.

Note: The above effectiveness criteria are the result of a 1980 AFIT research study (LSSR 63-80). Also, the listed order has no significance.

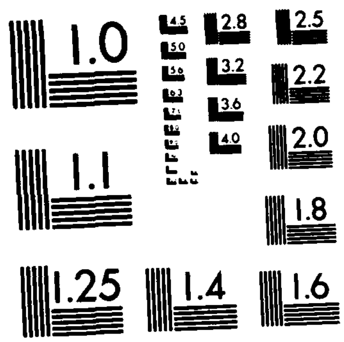
Atch 1-3

APPENDIX B

THE INTERVIEW INSTRUMENT

AD-A134 361 AN EVALUATION OF THE PERCEIVED EFFECTIVENESS OF RELIABILITY IMPROVEMENT W..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. 2/2

UNCLASSIFIED D R PARKINSON ET AL. SEP 83 AFIT-LSSR-58-83 F/G 14/4 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

DATE ______________________

PROGRAM ______________________

## GENERAL/DEMOGRAPHIC

1. CAREER FIELD OF MOST EXPERIENCE (AFSC) ______________
2. YEARS IN CAREER FIELD ______________
3. YEARS ON RIW PROGRAM ______________
4. OTHER RIW EXPERIENCE (IDENTIFY PROGRAM) ______________
5. PARTICIPATION IN OTHER RIW RESEARCH PROJECTS (IDENTIFY PROJECTS) ______________________________

   ______________________________________________

## PROGRAM EVALUATION

With respect to your RIW program, please use the following scale and question to rate each of the effectiveness criteria.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| LEAST | LESS | SLIGHTLY LESS | SAME AS | SLIGHTLY MORE | MORE | MOST |

Question: Based on your experience and expertise, how would you rate your program with RIW compared to similar programs without RIW?

____ Reliability

____ Maintainability

____ Acquisition cost

____ Equipment modification

____ Data collection

____ Contractor competition

____ Use rate

____ Supply system

____ Maintenance skill

____ Number of spares

____ RIW contract clause

## FUTURE RECOMMENDATION

With respect to the Air Force RIW program, please use the following scale and question to recommend the future use by the Air Force of the RIW concept.

| 1 | 2 | 3 |
|---|---|---|
| Discontinue | Undecided | Continue |

Question: Based on your experience and expertise, what would be your recommendation on the future use by the Air Force of the RIW concept?

## OPEN-ENDED QUESTIONS

1. Do you have any comments about your RIW program (good/bad) that you feel this research effort did not address?

2. Based on your recommendation on the future use of RIW's in the Air Force, what comments do you have to support this decision?

# APPENDIX C

# STATISTICAL OUTPUT

TABLE C-1. RESULTS: RESEARCH HYPOTHESIS ONE

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

CRITERIA OF THE AN-ARN 118 TACAN RIW PROGRAM
WITH NEUTRAL

| CASES | TIES | 17 -RANKS MEAN | 33 +RANKS MEAN | Z | 2-TAILED P |
|---|---|---|---|---|---|
| 66 | 16 | 24.32 | 26.11 | -2.162 | .031 |

TABLE C-2. RESULTS: RESEARCH HYPOTHESIS TWO

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

CRITERIA OF THE C-141 AHRS RIW PROGRAM
WITH NEUTRAL

| CASES | TIES | 13 -RANKS MEAN | 33 +RANKS MEAN | Z | 2-TAILED P |
|---|---|---|---|---|---|
| 55 | 9 | 18.19 | 25.59 | -3.321 | .001 |

TABLE C-3. RESULTS: RESEARCH HYPOTHESIS THREE

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

CRITERIA OF THE OMEGA NAV SET RIW PROGRAM
WITH NEUTRAL

| CASES | TIES | 20 -RANKS MEAN | 39 +RANKS MEAN | Z | 2-TAILED P |
|---|---|---|---|---|---|
| 77 | 18 | 30.15 | 29.92 | -2.129 | .033 |

TABLE C-4. RESULTS: RESEARCH HYPOTHESIS FOUR

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

CRITERIA OF THE CAROUSEL IV INS RIW PROGRAM
WITH NEUTRAL

| | | 17 -RANKS | 33 +RANKS | | |
|---|---|---|---|---|---|
| CASES | TIES | MEAN | MEAN | Z | 2-TAILED P |
| 55 | 5 | 22.06 | 27.27 | -2.534 | .011 |

TABLE C-5. RESULTS: RESEARCH HYPOTHESIS FIVE

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

CRITERIA OF THE F-16 ELECTRONIC COMP RIW PROGRAM
WITH NEUTRAL

| | | 22 -RANKS | 43 +RANKS | | |
|---|---|---|---|---|---|
| CASES | TIES | MEAN | MEAN | Z | 2-TAILED P |
| 77 | 12 | 30.73 | 34.16 | -2.591 | .010 |

TABLE C-6. RESULTS: RESEARCH HYPOTHESIS SIX

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

CRITERIA OF THE AF STANDARD INU RIW PROGRAM
WITH NEUTRAL

| | | 15 -RANKS | 41 +RANKS | | |
|---|---|---|---|---|---|
| CASES | TIES | MEAN | MEAN | Z | 2-TAILED P |
| 66 | 10 | 26.70 | 29.16 | -3.242 | .001 |

TABLE C-7. RESULTS: RESEARCH HYPOTHESIS SEVEN (TEST 1)

- - - - BINOMIAL TEST - PROBABILITIES FOR N = 6

| NUMBER OF EFFECTIVE RIW PROGRAMS (X) | ONE-TAILED PROBABILITY P(X) | CUMULATIVE PROBABILITY |
|---|---|---|
| 0 | .016 | .016 |
| 1 | .094 | .110 |
| 2 | .234 | .344 |
| 3 | .313 | .657 |
| 4 | .234 | .891 |
| 5 | .094 | .985 |
| 6 | .016 | 1.001 |

TABLE C-8. RESULTS: RESEARCH HYPOTHESIS SEVEN (TEST 2)

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

PROGRAM OF OVERALL RIW EFFECTIVENESS
WITH NEUTRAL

| CASES | TIES | 104 -RANKS MEAN | 222 +RANKS MEAN | Z | 2-TAILED P |
|---|---|---|---|---|---|
| 396 | 70 | 149.42 | 170.10 | -6.524 | .000 |

TABLE C-9. RESULTS: RESEARCH HYPOTHESIS EIGHT

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

RECOMMEN FOR THE FUTURE OF THE RIW CONCEPT
WITH NEUTRAL

| CASES | TIES | 1 -RANKS MEAN | 30 +RANKS MEAN | Z | 2-TAILED P |
|---|---|---|---|---|---|
| 36 | 5 | 16.00 | 16.00 | -4.546 | .000 |

APPENDIX D

COMMENTS ON OPEN-ENDED QUESTIONS

Table D-1. Open-Ended Comments by Program

AN/ARN 118 TACAN

1. The AN/ARN 118 was not a good choice for RIW.
2. System reliability was already built-in prior to contract award.
3. There was only one ECP submitted early in the program.
4. The use of RIW drove out other competitors.
5. Even with higher reliability, Warner-Robins ALC spared at the normal 20-22% level.
6. The use of RIW drove the contractor to design in more reliability.

C-141 AHRS

1. The Air Force could not accurately determine the MTBF of the C-141 AHRS.
2. Failure data was collected using the 66-1 Maintenance Data Collection System. This system did not work with AHRS RIW.
3. Together with 3-level maintenance and the RIW, we could not key on specific end item failures.
4. Many intangible benefits resulted from using the RIW. One example was that the contractor identified other aircraft problems that impacted on his RIW system.

OMEGA NAV SET

1. OMEGA was a good choice for RIW.
2. Dynell was a good, responsive company to work with.
3. Due to complex software and antennae, there were more ECPs than usual.
4. Using RIW enhanced the availability of OMEGA.

5. OMEGA RIW was probably the best in the Air Force as indicated by the positive attitude of the contractor, the good data collection by MAC, and the reliability of that type of equipment.

6. Use of RIW gives the contractor the flexibility to make money in the short term so that the Air Force can benefit in the long term.

7. There was too much administration of the RIW for government and contractor personnel.

8. There were too many ECPs submitted for which the government had to pay.

9. The RIW clause for contingency spares was too loose.

CAROUSEL IV INS

1. On the KC-135, the Air Force continually changed integration requirements which caused changes in software. This in turn affected the RIW.

2. The RIW was more effective getting reliability into the system.

3. Delco had high confidence in reliability improvement as evidenced by good internal procedures to insure reliability and prior commercial airline experience.

F-16 ELECTRONIC COMPONENTS

1. When the F-16 RIW was being considered (1976), there was little or no other RIW experience for comparison.

2. Because RIW options were firm fixed price options, obtained in a competitive source selection, these prices made subsequent decisions to exercise contract options much simpler.

3. Since F-16 RIW components were complex avionics, the Air Force could not achieve organic support for several years. Thus, the decision was to either buy sole source interim contractor support or buy the RIW in a competitive environment. Once the ICS prices were known, the selection of RIW was evident.

4. A RIW cost effectiveness analysis indicated the Air Force could save $100 million on the nine LRUs selected for RIW application.

5. Unconfirmed reports indicated the RIW yielded very little reliability improvement.

6. The F-16 RIW has been regarded as successful, primarily due to ICS cost avoidance.

7. The incentive to have the contractor improve reliability was not as good as planned.

8. The price paid for the RIW systems was $50-100 million less than non-RIW systems.

AIR FORCE STANDARD INU

1. Good data collection is the key to successful RIW management.

2. RIW requires a full-time manager.

3. With RIW, the program office gets good visibility into the program.

4. Under this RIW, all ECPs were no cost to the government.

5. Compared to the non-RIW INU on the F-15, the standard INU reliability increased 350%.

6. Reliability growth was forced into the system in the first two years through 29 no-cost ECPs.

7. A key to a successful RIW is a good technical specification.

8. The standard INU is 46% cheaper than the original F-16 INU.

Table D-2. Open-Ended Comments on Future Recommendations

1. RIWs should be considered for new technology items.

2. RIWs should be considered on smaller programs.

3. RIWs should be considered on simpler systems.

4. RIWs should be considered if the right equipment is selected for RIW application. That is the equipment should have initial low reliability with the potential for improved reliability.

5. RIWs should be considered for avionics programs.

6. RIWs should be priced in a competitive environment.

7. RIWs should be applied to programs with long production runs.

8. RIWs should be applied to black box (LRU) items only.

9. RIW is a good concept and the Air Force should push for continued use.

10. We should put cost to benefit gained.

11. We should contract for two units--one with and one without RIW.

12. The Air Force should continue using RIWs because RIWs have made more money for the Air Force than any other procurement program.

13. Program offices should get item managers and system managers involved early in formulating RIWs.

14. The Air Force should demand what it wants from the RIW. We cannot continue to assume the contractor will give us improved reliability if we do not ask for it.

15. The Air Force should specifically define what a failure is in the contract provisions.

16. We should continue the use of RIWs if the program has a definitive contract with a strong RIW clause.

17. The Air Force should develop a data collection system designed specifically to track RIW data.

18. We should apply RIWs more extensively.

19. The Air Force should insure that the contractor does not suboptimize his internal operations. That is, we should not force him to place priority on RIW items at the expense of other non-RIW items.

20. To make RIWs work effectively, the Air Force should insure that adequate time, money, and personnel are allocated to monitor the RIW.

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